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14. ABSTRACT

During cruises in May and June of 1999, 7991 km of single channel high resolution seismic data and 5278 km of chirp sub-bottom and side-scan sonar data were collected from the continental margin of the East China Sea (ECS) and Yellow Sea. When these data are pooled with data collected in this region during cruises in 1993 and 1996 the total data available for analyses is 15,408 km of seismic profiles and 13,295 km of chirp sub-bottom and side-scan sonar data along with 51 gravity cores. Copies of these data were provided to the Naval Oceanographic Office at Bay St. Louis, Mississippi. These data were processed to minimize noise and subjected to seismic stratigraphic analyses. Correlation of the data with published drill core descriptions indicate that the seismic profiles image stratigraphy that extends back to at least 200,000 years before present. The results of these analyses revealed that the stratigraphy of the margin was strongly impacted by glacially driven sea level fluctuations that produced regional unconformities that can be used to subdivide the stratigraphy into Lowstand (LST), Transgressive (TST) and (Highstand) systems tracts. The LST

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Final Report:

Use of Stochastic Modeling of Stratigraphic Relationships in High Resolution Seismic Reflection Data for Prediction of the Distribution of Acoustic and Geotechnical Property Variability in Near Surface Sediments on the East China Sea Continental Margin

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LONG-TERM GOALS:

Our research group is collecting and analyzing various levels of high-resolution seismic data and cores, for "ground-truthing" seismic facies, on continental margins with a spectrum of depositional boundary conditions. The long-term goal of this work is develop stochastic models of variation of geotechnical and seismic property distribution on margins subjected to a spectrum of depositional regimes. The importance of being able to produce these stochastic models is that they provide a means of making predictions (with assignment of statistical risk) of the variation of geotechnical and seismic properties, in areas where the only data that may exist for that margin, at the time that a prediction is needed, is information on physical oceanography or other gross descriptions of depositional conditions on the margin.

OBJECTIVES:

- Initially, collect high-resolution seismic data on margins with extreme depositional boundary conditions with objective of subjecting these data to sequence stratigraphic and seismic facies analyses to characterize the magnitude of the impact of variation in depositional regime on seismic stratigraphic architecture and seismic facies distribution.
- Quantify the nature of horizontal and vertical seismic facies heterogeneity within a sequence stratigraphic context, and develop stochastic models of seismic facies heterogeneity produced under depositional conditions described above.
- Assess the impact of the depositional processes from margins with extremely different boundary conditions on the stochastic models of vertical and horizontal distribution of seismic facies (and therefore geotechnical and acoustic properties).
- Determine the minimum data required to predict the distribution of seismic attributes on margins with various depositional boundary conditions by conducting sensitivity tests on survey spacing and associated changes in the distribution of mapped parameters.
- Numerically model sediment transport and deposition associated with storm events on evolving shoreline positions to simulate the stratigraphy that might be produced as a consequence of transgression in a storm dominated shelf environment. Model Results are tested with a chirp sonar and core database.

APPROACH:

The Carolina Stratigraphic Imaging Laboratory (CSIL) of the Department of Geological Sciences of the University of North Carolina, formerly the University of Alabama Seismic Stratigraphy Group of the University of Alabama (UASSG), researches the relationships between variations in sedimentary boundary conditions and the stratigraphy produced by these conditions. Limited work has been conducted on relating distribution of near-surface seismic facies and variability in depositional environment boundary conditions. The study area on the Western Pacific Continental Margin (WPCM) is a region with high sediment supply (4 times the amount of sediment per year as the Mississippi River) and large magnitude hydrodynamic sediment transport processes (tidal currents and large waves from typhoons and storms associated with the winter monsoon), so that there may be a high degree of correspondence between the sedimentary processes active on the margin and the preserved stratigraphy. In other words, it may be a situation where the sedimentary processes and recent stratigraphy may be in "dynamic equilibrium". We define dynamic equilibrium as a state in which there is a high correlation between the distribution of sediment character (size, sorting, composition etc.), types of bed forms, sedimentary deposit thickness, morphology and orientation and the character of sedimentary processes within environments (such as magnitude, duration, direction of sediment transport processes and total volume of sediment introduced by sediment source and proximity to the source). Most continental margins are not in dynamic equilibrium. These margins received most of their sediment during lowstands in sea level and the character of the sediment has little to do with the processes that operate on the margins today. Situations in which the continental margin exists in a state of dynamic equilibrium may be rare today and they may represent "End-Member" conditions, but understanding these systems is essential to understanding systems where the record of sedimentation is much less complete. In fact, the East China Sea (ECS) area contrasts quite distinctively with many other continental margins (such as offshore Alabama (one of CSIL's other study cites) and the STRATAFORM cites (offshore Eel River, California, and offshore New Jersey), and therefore provides an opportunity to infill the gaps in our knowledge of the spectrum of the links between processes and the stratigraphy of margins. Before the start of this project our attention was focused only on the inner and middle shelf environments of the ECS. This investigation involved acquisition and analyses of data from the outer shelf and slope environment of the ECS (Figures 1 and 2). Therefore, by completing this investigation we were able to characterize the entire margin.

CSIL simultaneously conducted an investigation of the 3-D variability of an area (the Alabama Shelf) with low sediment supply, microtidal conditions, and relatively infrequent storm events. Approximately 2,125 km of high-resolution (<1 m) Geopulse reflection seismic data were acquired within a 900 km^2 grid in an area that extends from $\approx$5 km offshore of the Alabama coast to the upper continental slope. We developed probability models of the distribution of seismic facies variability in this area and determined that the minimum data density required for making successful predictions of

physical property distribution within the incised valleys of the system given the set of boundary conditions described above.

The approach for this project was to: (1) acquire data from environments with a history of extreme depositional boundary conditions, (2) conduct sequence stratigraphic analyses of these data to identify units deposited within the same interval of time, and (3) conduct quantitative seismic facies analyses on the data sets so that the variations in seismic facies within each time-slice can be tracked spatially and later subjected to Analysis of Variance, Q-mode factor and binomial markov process analysis to identify non-random variations in seismic facies variability. We also investigated the utility of Fuzzy Logic in characterizing spatial variability of seismic facies in this system. This provides the stochastic model of spatial variability in acoustic property variability on the continental margin. We then test for sensitivity to survey spacing by under and over sampling isochron maps of seismic facies and thickness of systems tracts at various intervals, overlaying the maps, measuring deviations in orientation of features, and their spatial magnitude and conducting statistical tests to determine when the differences are significant.

WORK COMPLETED:

- During survey 221099 (May 1999) in the East China Sea (ECS) and the Yellow Sea (YS) 191 km of 210 cubic inch Generator Injector Air Gun data, 3,502 km of 15 cubic inch water gun data, 3,,217 km of chirp and side-scan sonar data, and 6 cores were collected. In June of 1999, during survey 221199, over the outer continental shelf and slope of the ECS margin 2,575 km of 50 cubic inch Generator Injector Air Gun data, 1,723 km of 15 cubic inch water gun data, 2,061 km of chirp and side-scan sonar data, and 11 cores were acquired. When the 1765 km of seismic and chirp sonar data that were collected during the ECS ASIAEX project in 2000 are added to the data collected during cruises in 1993, 1996 and 1999 (DEPSCOR cruises) the total data set collected by CSIL from the ECS continental margin is 15,408 km of seismic data, 13,295 km of chirp sub-bottom and side-scan sonar data and 51 cores.

- All of these data initially went to the Naval Oceanographic Office in Mississippi where they made duplicates of these data. These data were integrated into various products that the Naval Oceanographic Office provides to the fleet. CSIL received the data back from the Naval Oceanographic Office at the end of 1999. Although much of the processing of the seismic data was conducted while at sea, additional processing was required onshore at UNC and was completed during the 1^{sst} year of the investigation. The data were then loaded onto workstations for seismic stratigraphic and facies analysis.

- Seismic stratigraphic and facies analysis of the data was completed near the end 2004. This stratigraphic framework was used to create structure contour maps of important surfaces such as the ravinement surface (which lies under the veneer of sand that covers the seafloor), unconformities created by subaerial exposure (sequence boundaries). The framework was also used to produce isopach maps of important stratigraphic units such as highstand, transgressive, and lowstand deposits and maps of

the distribution of seismic facies (which are linked to variation of acoustic and geotechnical properties) within each of the important stratigraphic units.

- We have nearly completed our application of Fuzzy Logic modeling to assess the sensitivity of the stratigraphy of the ECS margin to variations in rates of sediment supply as well as rates and magnitudes of sea level change. A manuscript describing these results will be submitted for publication this fall (fall 2005). Stochastic characterization of the stratigraphy of the ECS margin is not yet complete. The stochastic characterization includes Analysis of Variance (ANOVA), Q-mode Factor Analysis, Binomial Markov Process analysis, and Regression Analysis. These techniques are used to quantitatively identify the non-random 3-dimensional variation in the distribution of physical properties and how these are related to long and short term variations in depositional boundary conditions (such as change in sea level (long-term), distance form sediment sources, major axes of typhoon paths, areas of strong tidal current velocity etc.). The long-term goal of the research of CSIL on margins is to assess the sensitivity of the distribution of acoustic and geotechnical properties on continental margins to variations of the depositional boundary conditions. This requires analysis and comparison of the distribution physical properties on continental margins (East China Sea, Yellow Sea, and offshore Alabama, Mississippi and Florida) with extreme sedimentary boundary conditions (ranging from very high sediment supply to very low sediment supply, multiple typhoons/hurricanes per year to one hurricane per six year interval, and macrotidal to microtidal conditions). So to achieve this long-term goal CSIL will continue with the stochastic characterization of the ECS margin even though the formal duration of this grant and project is over.

- The data collected during the 1999 surveys reduces the lateral interval between existing profiles on the ECS margin. These data were integrated with the existing data sets and sensitivity tests on impact of survey profile spacing on successful prediction of property distribution on ECS are still being conducted (Minimum Data Density Analysis (MINDDA)). Each data set used to create the various maps is being under-sampled and re-mapped through a number of iterations to assess the MINDDA required to characterize a given margin. Using data collected in 1993 and 1996, with the support of earlier grants, CSIL completed these types of analyses on datasets from the inner and middle ECS and a small segment of the outer shelf and slope. These assessments were also completed with data from the Yellow Sea and offshore Alabama, Mississippi and Florida (NE GOM). In order to achieve the goal of establishing the links between processes and the heterogeneity of margins, and to provide a stochastic characterization of these relationships, CSIL is integrating all of the ECS datasets and conducting another MINDDA of the ECS. This can then be compared to the Yellow Sea and NE GOM MINDDA results and an assessment of the quantity of data that are required to identify these systems will be available.

RESULTS:

Seismic stratigraphic analysis of the ECS profiles involved identification of key stratigraphic surfaces such as Sequence Boundaries (SB), Transgressive Surfaces (TS), and Maximum Flooding Surfaces (MFS). Stratal termination patterns, position within the

sequence and correlation to two drill core locations (Figures 3 and 4) where used to identify the Lowstand Systems Tract (LST), Highstand Systems Tract (HST) and the Transgressive Systems Tract (TST). Using these tools, surfaces and deposits that are associated with Oxygen Isotope (O.I.) Stages 8, 7, 6, 5, 4, 3, 2, and 1 (Figure 5) were identified in the study area. Three complete sequences were mapped over nearly all of the study area: Sequence 1 (O.I. Stages 1 and 2), Sequence 2 (O.I. Stages 4 through 2) and Sequence 3 (O.I. Stages 6 through 4).

The LST deposits of the ECS are amazing in the extent of their lateral continuity. The LST can be traced laterally along depositional strike between 500 to 600 km and between 300 to 400 km along depositional dip and ranges between 10 and 20 meters in thickness (Figures 6 and 7). The form of ECS LST deposits is essentially a sheet. LST deposits on other margins typically are restricted to incised valleys and usually have an along strike extent that is on the order of a few 10's of km at most. The LST deposits of the ECS lie directly above a Sequence Boundary (an unconformity produced by subaerial exposure of the continental shelf during sea level lowstand) that is identified by the abrupt termination of underlying reflections. The LST deposits lie beneath a transgressive surface (an erosional surface produced as sea level rises and the surf zone translates landward over areas of the shelf that were exposed subaerially at lowstand) that is identified by abrupt termination of underlying reflections and the high amplitude of this terminating reflection. Incision of the ECS LST deposits is relatively rare and is restricted to locations where there is a local increase in the gradient (such as at the front of lobes), which are associated with the topography at the top of the underlying strata (Figures 8 and 9). Due to the limited incision, the LST deposits are essentially perched on the shelf and there is limited bypass of sediment to the basin. This is very significant because it radically alters the character of slope and basin deposits and the structural stability of the slope. Essentially the slope and basin are relatively sediment starved, so there is no creation of over steepened slopes that fail and create all sorts of deformation to the slope. There is also an absence of the coarse-grained deposits in the basin, so there are no large fans that one would expect to find in a basin that lies down dip from 2 of the world's top 4 rivers in terms of sediment discharge. Seismic facies of the LST on the shelf consist of chaotic to channel shaped reflections (some displaying limited lateral accretion) (Figure 3). In down-dip locations the LST facies transition into offlapping, variable amplitude, variable frequency, and laterally continuous seismic facies (Figures 3 and 7). The chaotic LST facies comprise a sheet of relatively homogeneous deposits with similar acoustic attributes while the offlapping stratified LST deposits have a more lobe like morphology (Figure 3, 7 and 9). The stratified facies are vertically heterogeneous and laterally homogeneous.

The TST deposits of the ECS lie above the LST deposits (Figure 3). The reflection at the base of the TST deposits often truncates underlying LST reflections and usually has a high-amplitude. The TST is either in the form of a laterally extensive, very thin layer (0.25-4 meters) of a couple of parallel, relatively high amplitude reflections, or it thickens (5-20 meters) to a more ridge-like form containing inclined reflections (Figure 3). The ridge-like TST deposits are usually confined to depressions in the topography on the top of the underlying systems tract. The top of the TST is defined by downlap of overlying

reflections onto the more flat-lying reflections of the TST and this interface represents the Maximum Flooding Surface (MFS).

Highstand (HST) deposition is focused in lobes on the continental shelf (Figure 8). It is thickest and most laterally extensive on the outer shelf and limited to isolated, erosional-remnants on the inner shelf. Highstand deposits of the ECS lie above the MFS and range from downlapping, variable amplitude, variable frequency, and laterally continuous seismic reflections (Figure 3). In up-dip locales the reflections of the HST are flat-lying and parallel, while in down-dip locations the reflections assume a subparallel-offlapping orientation. Often, there is a transition from the parallel reflections to chaotic reflections in up-dip locales (Figure 7). The top of the HST is defined by toplap and erosional truncation of the upper HST reflections. The surface along with the toplap and truncation occur is a Sequence Boundary and this marks the top of a depositional sequence.

The two most important factors controlling the stratigraphy of a margin are the accommodation and the volume and rate of sediment supply. Accommodation variation on the ECS margin is much like that of other margins in that it is significantly controlled by eustatic change which is ~120 meters in the interval of interest (Figure 5). The element of accommodation on the ECS margin that is different from other margins is the volume of accommodation created by the extreme width (~500 km) and depth (150-190 m at the shelf edge) of the margin (Figure 10). Climate is one of the important elements controlling the sediment supply to the margin and precipitation is key because it generates the run-off that transports the weathered sediment from the source area to the depositional site on the margin. The precipitation in the ECS region varies by a factor of 3 (200 – 700 mm/yr.) during the global climate transitions from interglacial (HST) to glacial (LST) (Figure 11).

The interaction of the changes in sediment supply and accommodation control the evolution of the stratigraphy that was imaged on the ECS margin by the high-resolution seismic profiles. The high-resolution ((1 meter) seismic stratigraphic analysis of the ECS margin reveals that the the Lowstand (LST) deposits on the shelf (cut-and-fill, aggradation without much lateral accretion) are laterally extensive (~500 km along strike) and are thickest in inner shelf (Figures 3, 6, 7 and 9). LST incision of the shelf is localized to the HST lobes (Figure 9), in areas where there is an increase in gradient such as at the front of lobes. LST incision of the shelf edge is rare. Essentially the LST deposits are perched on the shelf and there is limited bypass of sediment to the basin. Highstand (HST) deposition is focused in lobes on the continental shelf, thickest and most laterally extensive on the outer shelf and limited to isolated "pods" on the inner shelf (Figures 6 and 8). Transgressive deposits are either thin (<5 meters) sheets or long ridges that contain inclined reflections (Figure 3). The ridges appear to be localized to areas where the Transgressive (TST) deposits are infilling depressions in the pre-existing topography.

The character of the LST deposits on the ECS margin is clearly influenced by both accommodation and climate change. The shelf edge depth of between 150 and 190 meters is greater than the magnitude of the largest decreases in sea level elevation over

the last 400,000 years. Consequently, when sea level was at its lowest elevation, during glacial climate intervals, the shelf edge (upper slope) was not exposed (Figures 5 and 10). This is important because the continental slope of margins typically have the steepest gradient of the margin and as rivers flow over this gradient the velocity of flow increases and this causes increased erosion and initialization of incision of the margin. The shelf edge was not exposed on the ECS margin because the depth of the shelf edge is greater than the fall in sea level (Figures 5 and 10). Therefore, the rivers of the ECS margin did not encounter the higher gradient of the shelf edge and widespread incision of the ECS shelf was not initialized. This is a very different response to sea level fall than occurred on most of the world's continental margins, where shelf edge depths average between 120-130 meters. The gradient of the ECS shelf is at or less than that of the fluvial systems that crossed it during the lowstand in sea level. Yet, there are a few places on the shelf where incision does occur. Close study of the distribution of this incision reveals that it is focused on the front of depositional lobes where there is a very localized increase in gradient (Figures 8 and 9). In all of the other portions of the shelf, the rivers crossing the lower gradient (less than the river's gradient) of the ECS shelf, as sea level fell, no longer had the velocity to keep sediment entrained and this promoted widespread aggradation and avulsion (Figures 3, 7 and 9). On the ECS margin it clear that the physiography of the margin played an important role in the formation of the laterally extensive LST deposits imaged in the ECS seismic profiles.

Climate also played an important role in shaping the character of the ECS LST deposits. During the glacial maxima, the precipitation in the region decreased by a factor of 3 (Figures 5 and 11). This reduces the discharge of the rivers and they do not have the competence or capacity to transport the sediment that is supplied by the drainage basin. This causes the rivers to aggrade and avulse, producing a laterally extensive, braided LST architecture on the shelf. Another significant impact of the reduced discharge during the LST is that discharge is rarely large to fill broad accommodation and bypass shelf, so during LST intervals the basin is sediment starved, despite presence of 2 of the top 4 rivers in the world, in terms of sediment discharge. This is a response to lowstand eustatic conditions that is not consistent with the general sequence stratigraphic model which states that the lowstand is the interval in which large volumes of sediment bypass the shelf and are deposited on the slope and in the basin in fans. This is an extremely significant result of the analyses conducted during this project and it clearly indicates that when attempting to use stratigraphy to assist with predicting the heterogeneity of the distribution of acoustic properties on the margin one must consider more than just the change in accommodation.

Accommodation and climate change also influence the architecture of the HST deposits on the ECS margin. Because there is limited incision of the margin during the lowstands, most of the deposition on the margin during the highstand of eustasy in the form of lobes, as opposed to estuary fill. Due to the wide breadth of the shelf and depth of the shelf edge, there is a large volume of accommodation that must be filled before progradation beyond the shelf can occur. Consequently, the HST deposits are largely restricted to the shelf. During HST (interglacial) intervals precipitation is 3 times higher than the rate during lowstands. Consequently, any relief that may have been created during the

lowstand is quickly filled and progradation onto the shelf produces lobes of HST deposits on the ECS margin, as opposed to having the HST deposits limited to the infill of incisions and the inner shelf, as occurs on margins where sediment supply is low. Lobe formation on the shelf during highstands is important because it creates the local relief (steeper gradient at the lobe front) that initiates limited incision during lowstands (such as incision of Oxygen Isotope Stage 4 deposits into the O.I. Stage 5 lobe as well as O.I. Stage 2 incision into the O.I. Stage 5 lobe).

This investigation reveals that there is a strong relationship between the long and short-term processes operating on the ECS margin and the stratigraphic architecture of the margin. These processes combined to produce an architecture that is quite different from that of many other margins. It provides a clear example of how other factors (margin physiography and climate (sediment supply)), beyond sea level driven changes in accommodation, plays a significant role in shaping the stratigraphy. Therefore, these other factors may be as important, or perhaps more important, in controlling the nature of the heterogeneity in the distribution of sediment types, which leads to variation in the distribution of acoustic properties in the near-surface environment.

Stratigraphy on the WPCM is quite different than stratigraphy developed on continental margins with much lower sedimentation rates and less ability to disperse sediment. Data from the continental margin of the Gulf of Mexico (GOM) indicate that the stratigraphy of margins with a shelf edge depth that is at, or less than 120 m, subjected to low energy depositional conditions, and low sediment supply consists of: highstand (HST) deposits of wide lateral extend and relatively homogenous reflection character, lowstand (LST) incisions that are widely dispersed along the margin, narrow (few km to 10 km) and shallow (10's m), but with complex fill and transgressive (TST) deposits consisting of thin (1-2 m) sheets of sand or mud. On the ECS margin, which is subjected high-energy depositional conditions, high sediment supply and a shelf edge that is much deeper than 120 m, the highstand (HST) deposits are moderately thick and continuous with similar seismic facies as seen in the GOM systems, but in inner shelf locales the HST is restricted to a few isolated remnants "floating" in a matrix of LST. LST deposits are are laterally extensive sheets (100's km wide and long and a few 10's m thick) rather than the isolated incisions of the GOM. Due to the tremendously high sediment supply the fill of the ECS margin, any of the few incisions that may occur have a homogenous fill, as does most of the rest of the LST. The TST of the ECS is similar to the GOM in that it primarily consists of very thin (1-3 m) sheets (100's km wide and long), but it differs due to the presence of clusters of ridges that are 10's m high a few km wide and 10's of km long. The large tidal range of the ECS margin causes the difference in the TST of the two systems. The ridges of the ECS are associated with very high tidal range and current velocities. These studies indicate that we are on the verge of being able to use data on the processes operating on a margin to predict the character of the acoustic heterogeneity of a margin.

Sensitivity analyses of the data density (MINDDA) required to identify the positions, morphology and fill of incised valleys of the GOM system are complete. Incised valley structure contour maps require a sample interval of 9.4 km to identify their character. A

sample interval of 2.3 km is required to characterize the heterogeneity within the incised valleys of the GOM system. Preliminary MINDDA of the ECS data suggests that sample intervals on the order of 10 to 20 km may be adequate for characterizing the heterogeneity of the LST in areas where incision is not present. Ten to 20 km sample interval may also be adequate for characterizing the HST in the middle and outer shelf locales, but in the inner shelf where the HST consists of eroded remnants a higher sample density is required.

IMPACT/APPLICATIONS:

The scientific impact of this work is that laid the ground-work for quantification of the relationships between depositional boundary conditions and near-surface seismic/geotechnical properties distribution on continental margins. This therefore leads to more reliable estimates of these properties in areas where it is either difficult to acquire such data, or it is necessary to design a survey that will quickly provide needed insight, with a given level of risk of a bad prediction. It also leads to more successful design of transmission loss surveys and acoustics experiments on the role of bottom interaction on sound propagation in continental shelf environments. This obviously has impact in areas such as oil and gas exploration and production, environmental waste containment, and of course, defense related issues on continental margins.

TRANSITIONS:

Understanding the process-response relationship between depositional conditions and seismic facies distribution leads to improved understanding the nature of the heterogeneity of the distribution acoustic properties on a continental margin. The Naval Oceanographic Office has used the results of our analyses to design and conduct more successful transmission loss surveys on the WPCM. They also take data that we provide to them and integrate it into databases that they provide to the U.S. Navy for operations.

PUBLICATIONS:

Refereed Papers that were completed via funding of student support or through use of data acquired with this grant are listed below:

Bartek, L.R., and Warren, J.D. (to be submitted fall 2005), Concurrent Incised and Unincised Valley Systems and Their Geomorphic Control During Quaternary Lowstands on the East China Sea Continental Margin, Journal of Sedimentary Research,.

Warren, J.D and **Bartek, L.R.**,. (to be submitted summer 2005), The Metastable Fluvial Shelf System (MFSS): An Alternative Hypothesis to Lowstand Unincised Fluvial Bypass on the East China Sea Continental Margin, Sedimentology.

Warren, J.D and **Bartek, L.R.**,. (to be submitted summer 2005), Revised sequence-stratigraphy framework and classification of the ECS continental margin (submit to Marine Geology, JSR or Cont Margin Research)

Miller, K. and **Bartek, L.R.**, (submitted and currently revising), Paradoxical Sediment Starvation in the East China Sea and Okinawa Trough Region, Marine Geology.

Flaum, J.A., **Bartek, L.R.** and Keen, T.R., (submitted and currently revising), Stratigraphy of the Transgressive Systems Tract of a Continental Margin with High Sediment Input and Frequent and Intense Storms: A Comparison of Model Output with Chirp Sonar and Core Data-East China Sea. Sedimentology.

Bartek, L.R., Cabote, B.S., Young, T. and Schroeder, W., 2004, Sequence Stratigraphy of a Continental Margin Subjected to Low-Energy and Low Sediment Supply Environmental Boundary Conditions: late Pleistocene-Holocene Deposition offshore Alabama, USA, in John B. Anderson and Richard H. Fillon eds., Late Quaternary Stratigraphic Evolution of the Northern Gulf of Mexico Margin, SEPM Special Publication, Tulsa, OK, v. 79, p. 85-109.

Wellner, R., and **Bartek, L.R.,** 2003, The Link Between Base Level, Climate, Shelf Physiography and Large Incised Valley Development: A Modern Example from the East China Sea, Journal of Sedimentary Research, v. 71, No. p. 926-940.

Warren, J.D., **Bartek, L.R.,** Wang, P.P., Ramsey, H.R., 2003, Relative sea-level modeling using fuzzy logic. Proceedings from the Joint Conference on Information Sciences, September 26-30, 2003, Cary NC, p. 117-120.

Warren, J.D. and **Bartek, L.R.**, 2002, The Sequence Stratigraphy of the East China Sea: Where are the Incised Valleys?, In J.M. Armentrout and N.C. Rosen, (eds), Sequence Stratigraphic Models for Exploration and Production: Evolving Methodology, Emerging Models and Application Case Histories, Proceedings of the 22nd Annual Gulf Coast Section SEPM Foundation Bob F. Perkins Research Conference, p. 729-738.

Abstracts and Invited Presentations that were completed via funding of student support or through use of data acquired with this grant are listed below:

Bartek, L.R., Wellner, R., and Warren, J.D., 2004, Climate and Shelf Physiography—Their Role in Shaping Sequence Architecture: An Example from the East China Sea, Invited Talk, American Association of Petroleum Geologists Annual Convention (April 18-21, 2004), Dallas, Texas, Abstracts Volume, p A11.

Warren, J.D. Ramsey, H.R., Wang, P.P.' and **Bartek, L.R.**, 2003, Relative Sea Level Modeling using Fuzzy Logic, Proceedings of the 7th Joint Conference on Information Sciences, Cary, NC, Sept. 26-30, 2003. p. 117.

Warren, J.D. and **Bartek, L.R.**, 2002, The Sequence Stratigraphy of the East China Sea: Where are the Incised Valleys? *Invited Paper,* In J.M. Armentrout (ed.), Proceedings of the 22nd Annual Gulf Coast Section SEPM Research Conference- Sequence Stratigraphic Models for Exploration and Production: Evolving Methodology, Emerging Models and Application Case Histories, Dec. 8-11.

Bartek, L.R., 2002, Impact of Climate Change, Eustasy, and Margin Physiography on the Geologic Record of Continental Margins, *Keyonote Address*, American Geophysical Union Chapman Conference on Continent–Ocean Interactions within the East Asian Marginal Seas, San Diego, November 11-14, 2002.

Wood B.J., **and Bartek, L.R.**, 2002, Determination of the Minimum Data Density Requirements to Characterize the Heterogeneity of the Yellow Sea Continental

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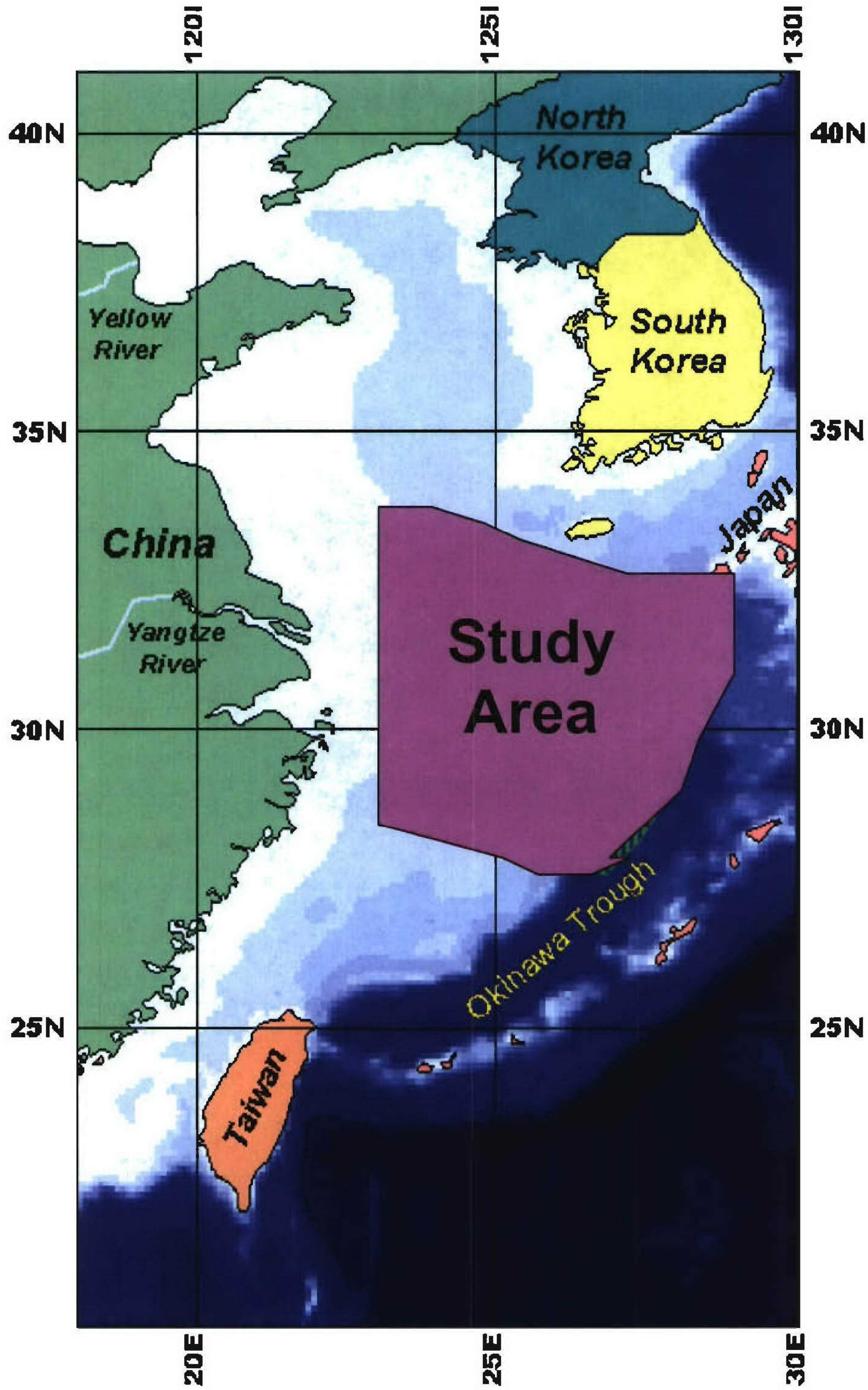

Figure 1: Map illustrating the location of the East China Sea Study area.

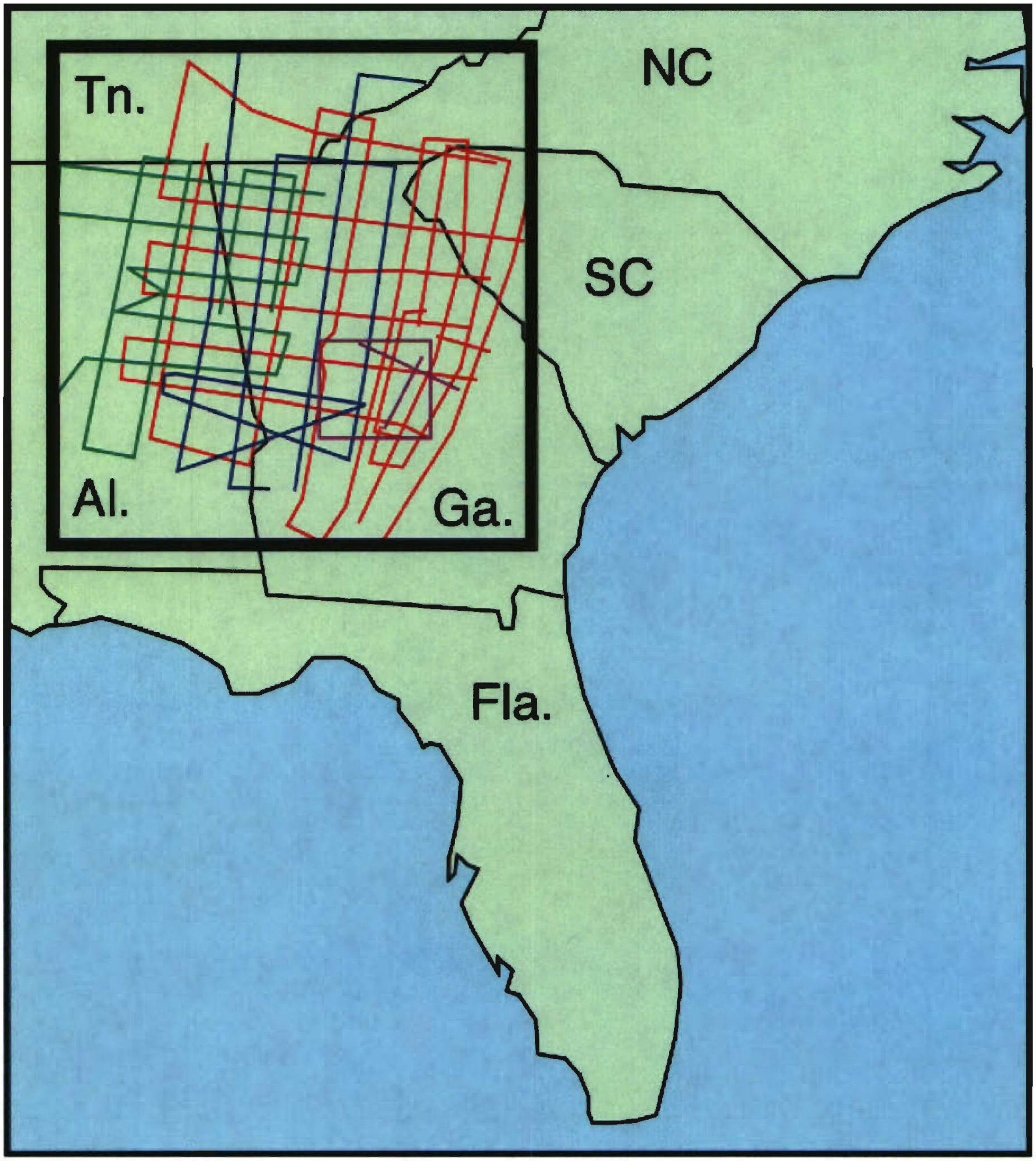

Figure 2: Map of the position of the seismic profiles used in this study. Profile locations are projected on a map of the SE USA to provide perspective on the volume of data involved in this investigation. The colors of the lines correspond to the cruises during which the data were acquired. The data acquired using resources from this grant in 1999 are red lines.

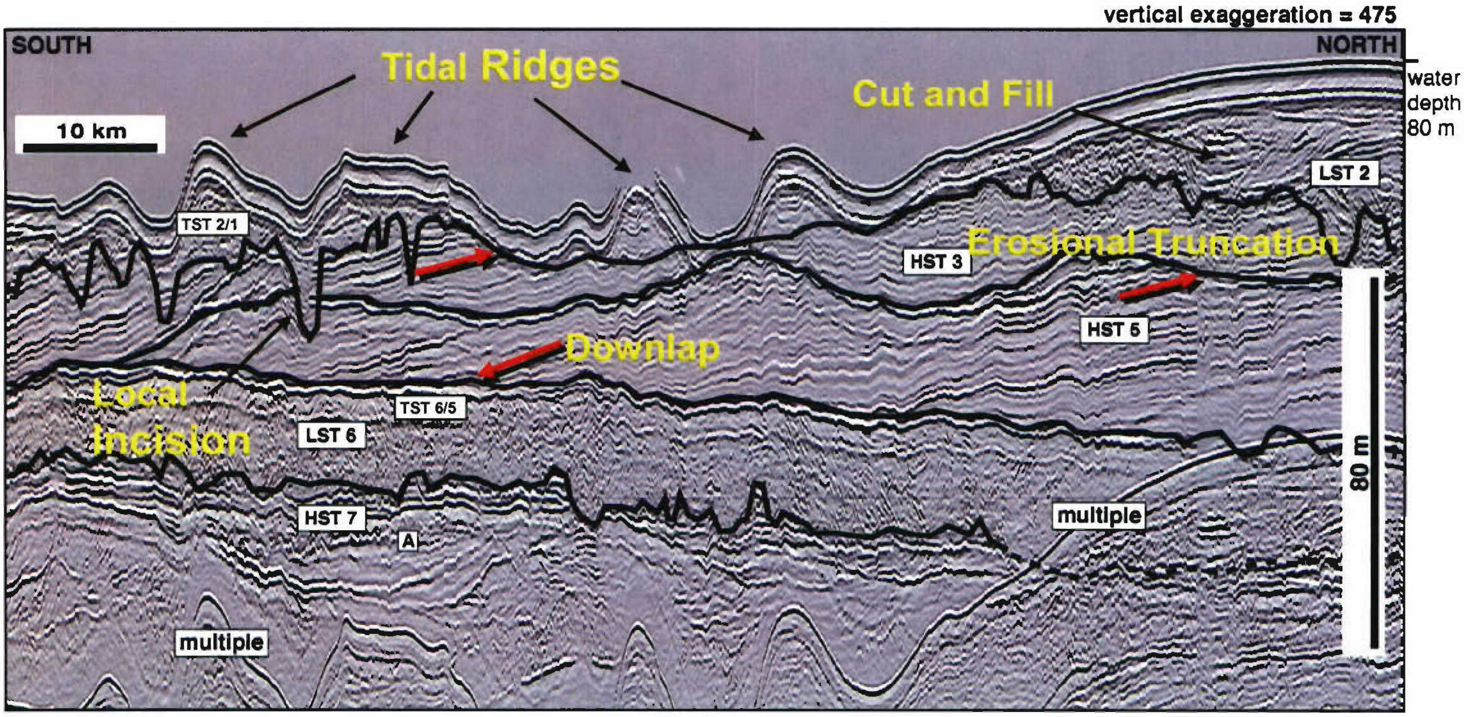

Figure 3: Strike-oriented seismic profile illustrating some of the characteristics of the ECS stratigraphy. Note the terminations (downlap and erosional truncation) that define the boundaries of stratigraphic units and the chaotic to channel-form facies and localized incision LST 2 and 6, the variable amplitude, variable frequency and wide lateral extent of the reflections of HST 3 and 5 and the thin and laterally extensive and high amplitude reflections of TST 6/5 and ridge-form of TST 2/1.

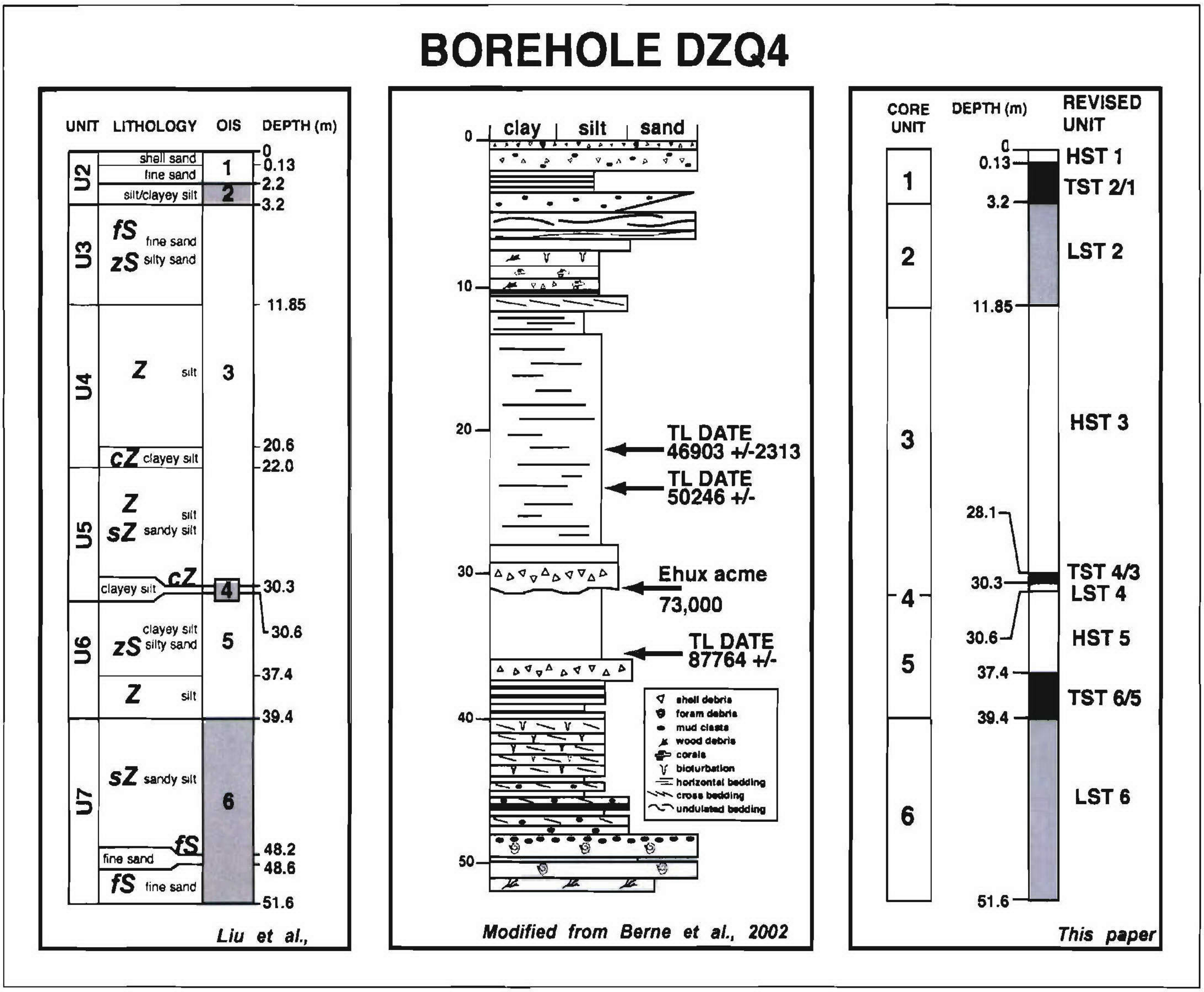

Figure 4: Graphic logs illustrating the chronology, lithofacies and sequence stratigraphy of core DZQ-4. This is one of the two cores in the ECS study area that correlate to the seismic profiles that are used to provide a chronology for the seismic stratigraphic units, lithofacies for associated seismic facies and environmental interpretations of the seismic facies. LST, TST and HST refer to systems tracks and the numbers after the systems tract designations correlate to Oxygen Isotope Stages (see Figure 5).

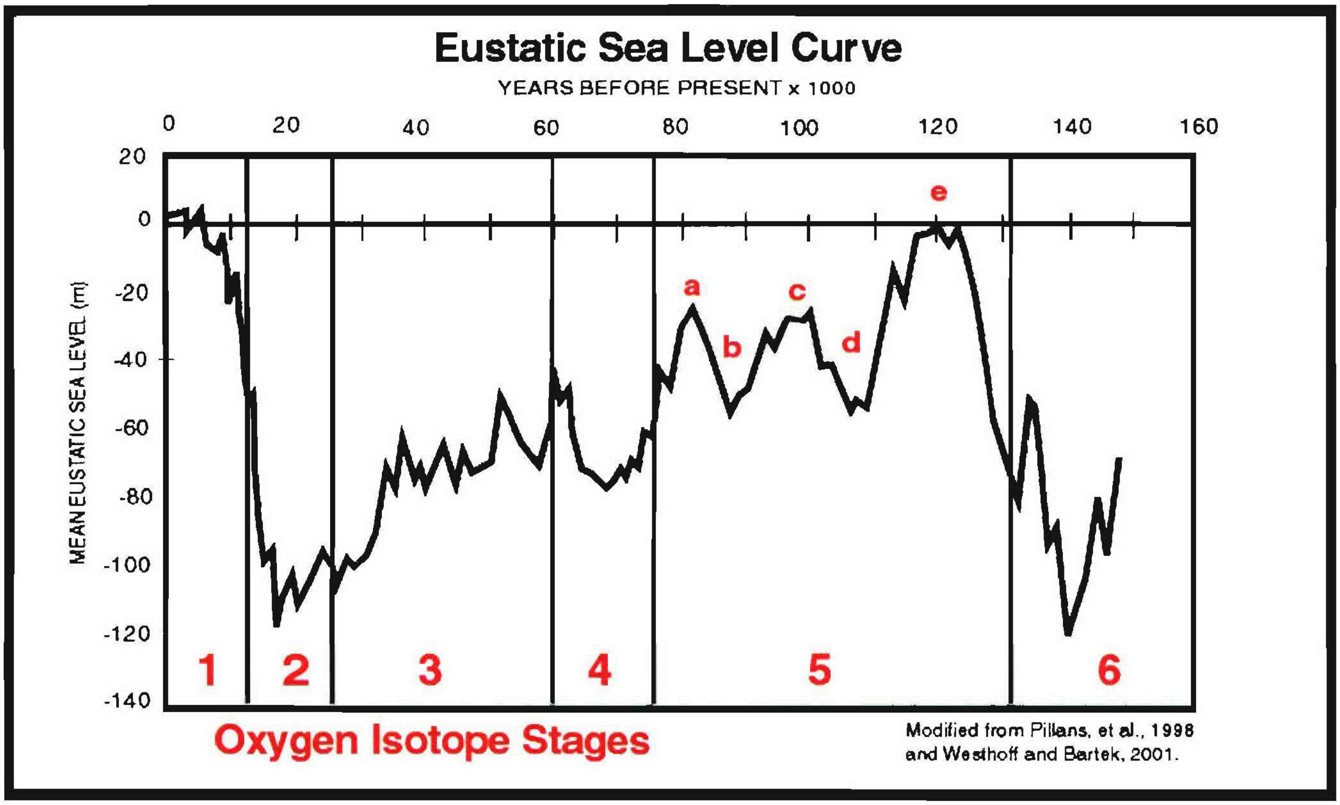

Figure 5: Plot of the variation in eustatic sea level (as derived from temporal changes in oxygen isotopes) versus time. Note that the sea level variation in the interval of interest is on the order of 120 meters. The red numbers at the bottom of the chart correspond to oxygen isotope stage designations. The odd numbers correspond to warmer intervals (interglacial events) when sea level is high and the even numbers correspond to colder intervals (glacial maxima) when sea level was lower (as much as 120 meters.

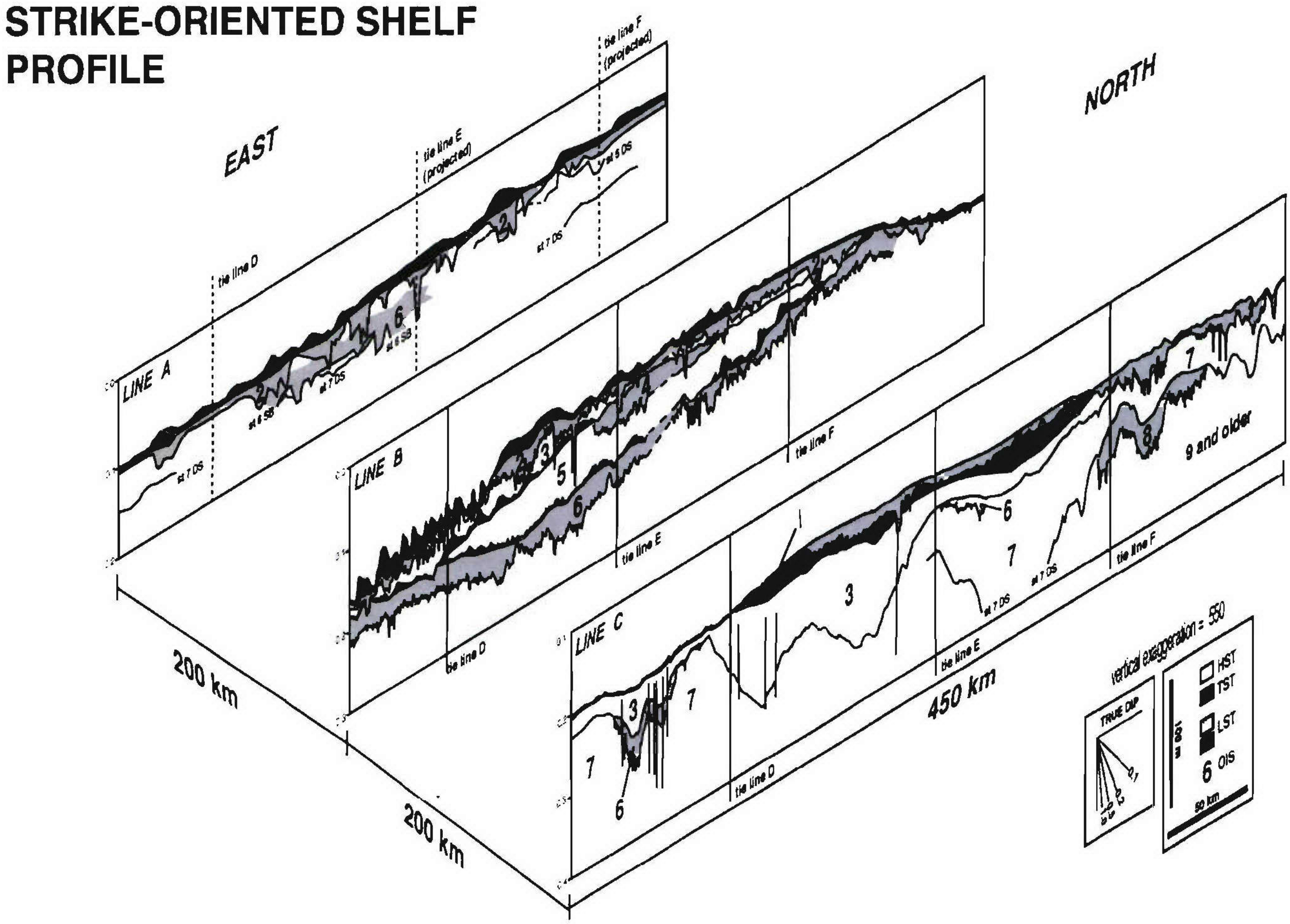

Figure 6: A series of strike-oriented cross-sections derived from seismic profiles illustrating the wide lateral extent of seismic units and the variation of thickness of the units. Light and dark grey unis correspond to LST, white units are HST and TST is black. Note that the extent of HST is much more restricted up-dip (Line A) and that LST fluvial units can be traced continuously along strike more than 450 km and 400 km up and down dip.

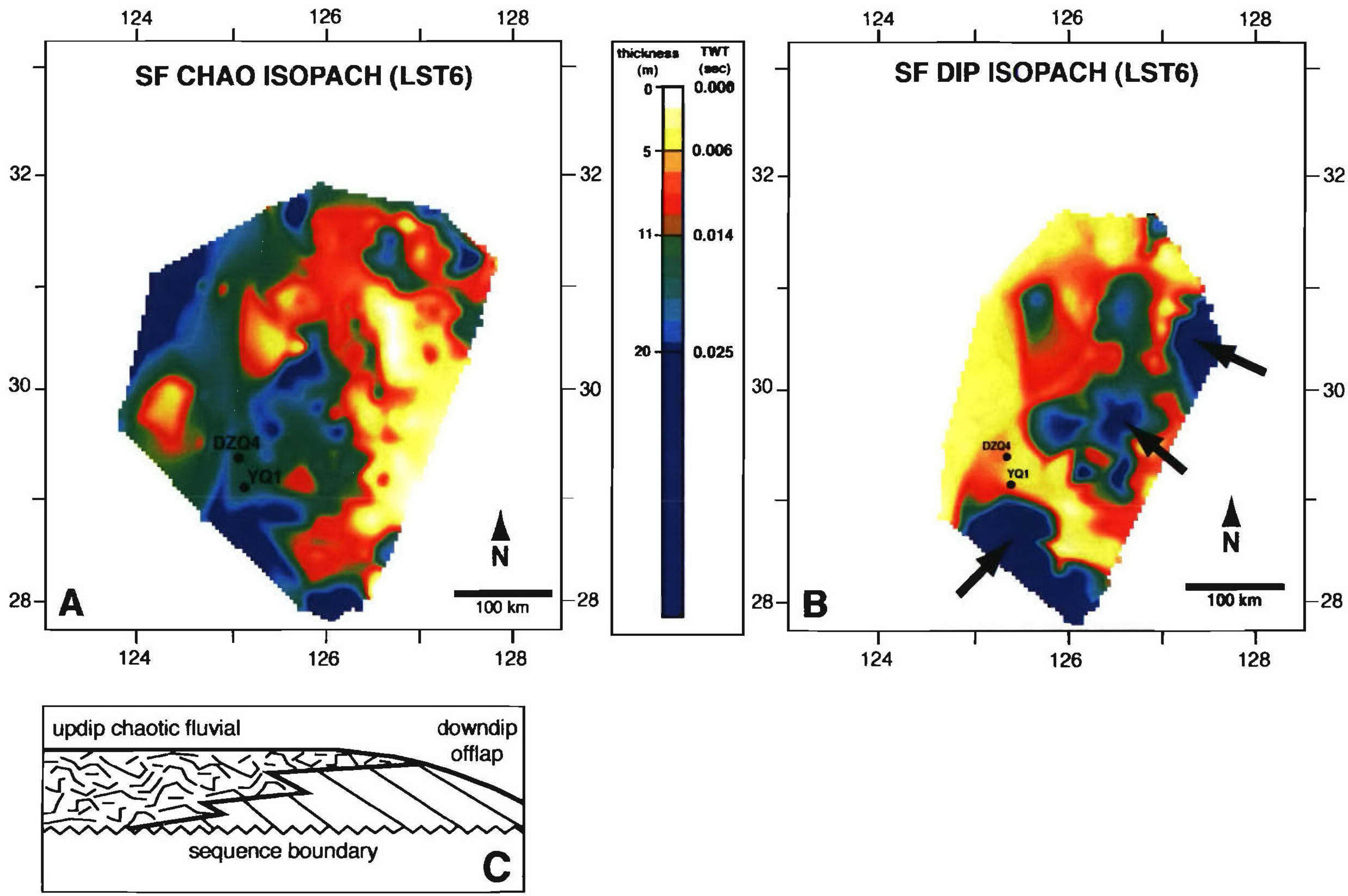

Figure 7: Maps illustrating the wide lateral distribution of LST deposits in the ECS stratigraphy. **A** shows the wide distribution of the chaotic fluvial facies that thin down-dip. **B** shows the distribution of three lobes of the LST facies of continuous, variable amplitude and variable frequency reflections. They are only found in down-dip locations. **C** shows the up-dip to down-dip variation in facies within the LST.

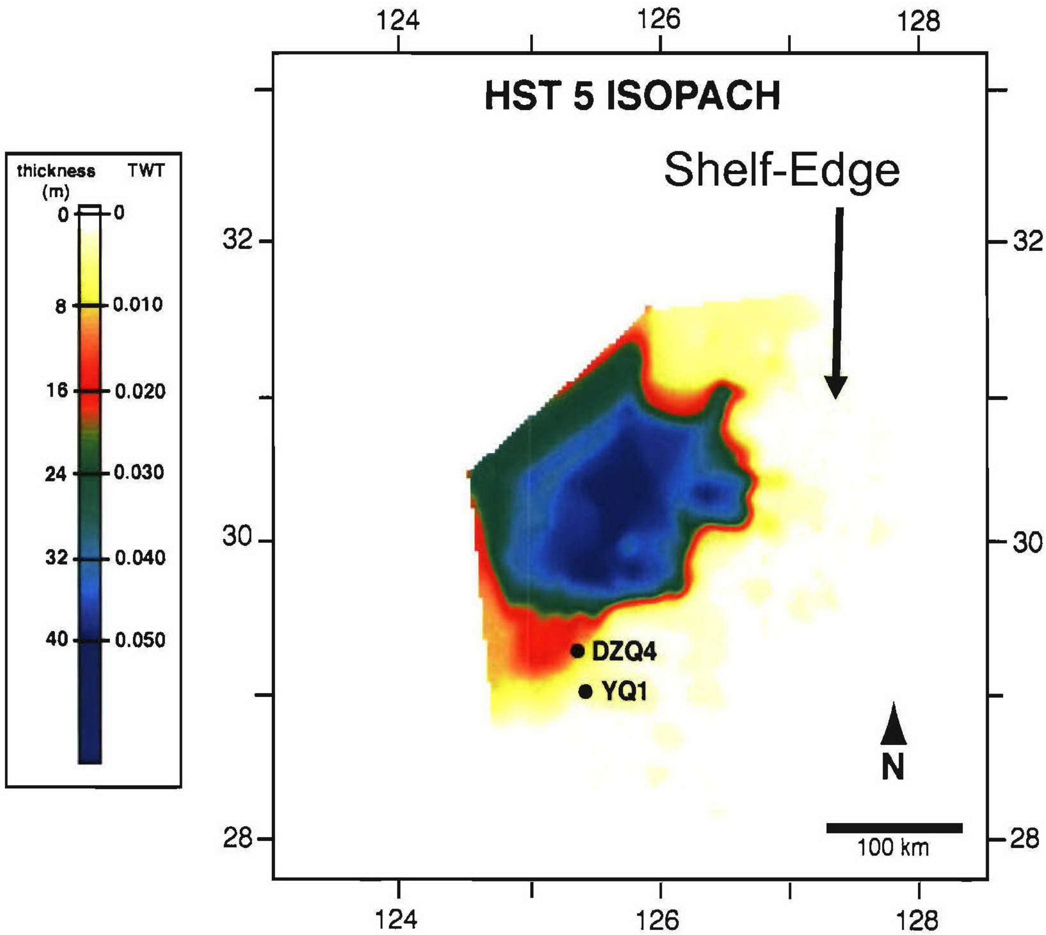

Figure 8: Isopach map showing a lobe of HST deposits (HST 5). These are created by the higher influx of sediment during the HST, but because the accommodation is too large a lobe is formed that is not able to prograde over the edge of the margin. The change in gradient across the front of the lobe causes rivers flowing across the shelf during LST to accelerate, creating localized incision as seen in Figure 9. DZQ4 and YQ1 mark the locations of two cores that were acquired by Chinese scientists, who published extensive information on ages and composition of sediment in the cores. Some of this information was used to constrain our interpretations of the seismic data.

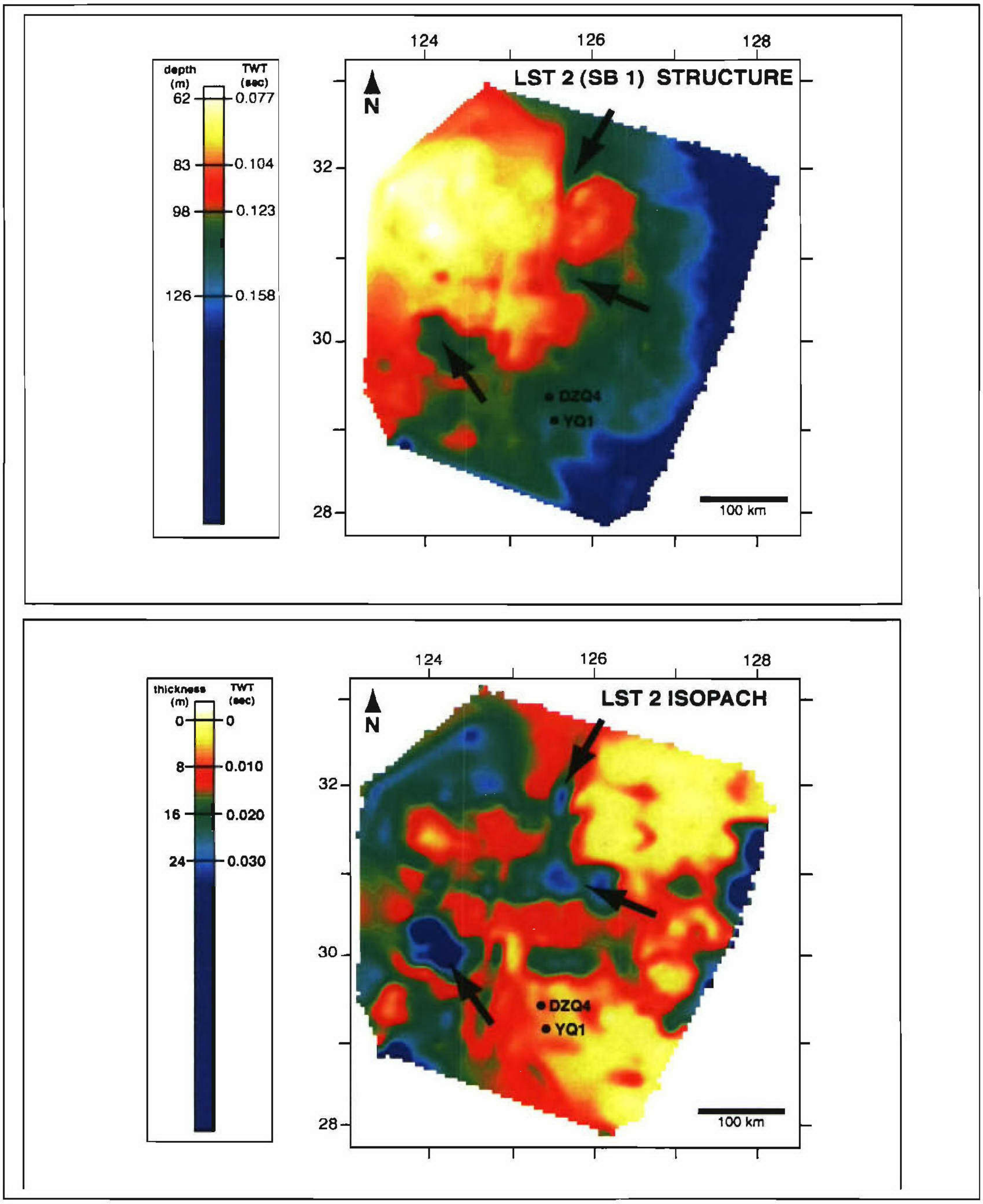

Figure 9: Structure (**A**) map illustrating the relief of the unconformity (subaerial exposure surface during LST) that underlies the Oxygen Isotope Stage 2 (OIS 2) deposits. The lobe morphology is associated with the OIS 5 HST depositional lobe (HST 5), see Figure 8. The arrows denote the locations of incision at the front of the lobe. The incisions are located where the surface gradient increases markedly. The increase in gradient across the front of the lobe causes rivers flowing across the shelf during LST to accelerate, consequently increasing the capability of the rivers to erode down into the underlying substrate, creating incisions. (**B**) Isopach map showing the variation in thickness of the OIS 2 LST sediment, which were deposited above the unconformity illustrated in (**A**). Note the wide lateral extent of thick (15- 20 m) fluvial deposits up-dip from the lobe front, the localized increases in thickness (at the 3 sites of incision) of the deposits across the steeper gradient of the lobe-front, and the change back to wide lateral distribution of thinner (3-7 m) fluvial deposits down-dip of the lobe-front, where the gradient decreases again.

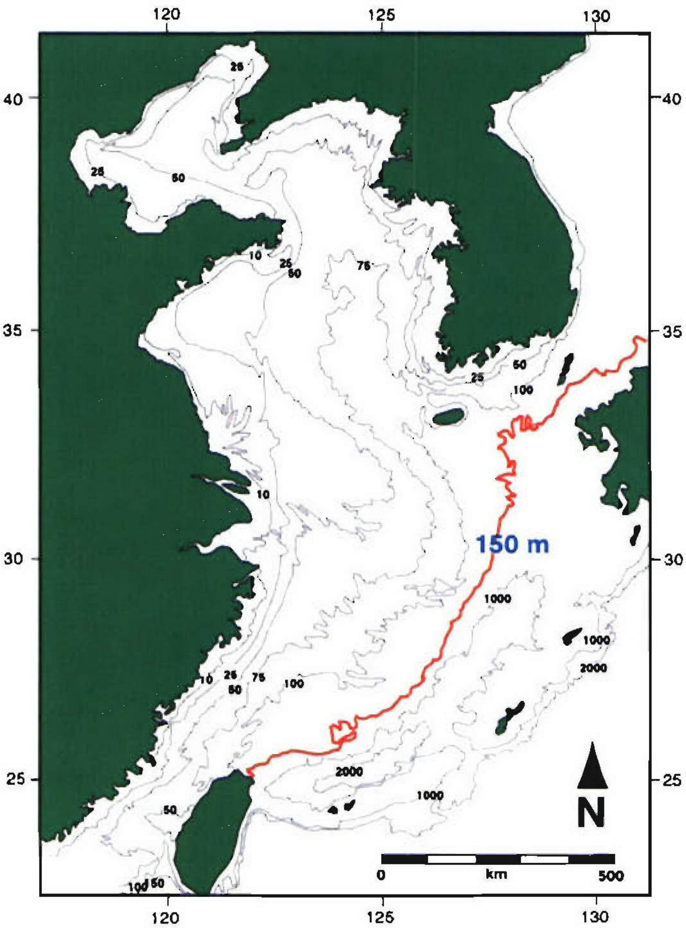

Figure 10: Bathymetric map of the ECS. The red line marks the 150 m isobath and the edge of the shelf. Note the very wide breadth of margin and the depth of the shelf/slope break, which ranges between 150-190 meters. This creates very large accommodation that must be filled before sediment can bypass the shelf and deposit on the slope or basin. Comparison to the eustatic curve in Figure 5 reveals that sea level did not decrease below ~120 meters in the last few 100,000 years. Consequently, the shelf edge and upper slope were not exposed and this prevented river systems crossing the shelf during LST from encountering the steeper gradients that would cause the rivers to increase velocity and to incise. This has significant impact on the stratigraphic architecture of the ECS margin, which lacks extensive dissection of the margin by incised valleys, rather the LST deposits consist of laterally extensive fluvial deposits on the shelf and limited sedimentation on the slope and basin. The lack of sediment in the basin is manifest by Pliocene volcanic rocks exposed at the seafloor and the absence of fans and various slope failure elements. This is not what one would expect to find in a basin located downdip from 2 of the top 4 rivers in the world, in terms of sediment discharge.

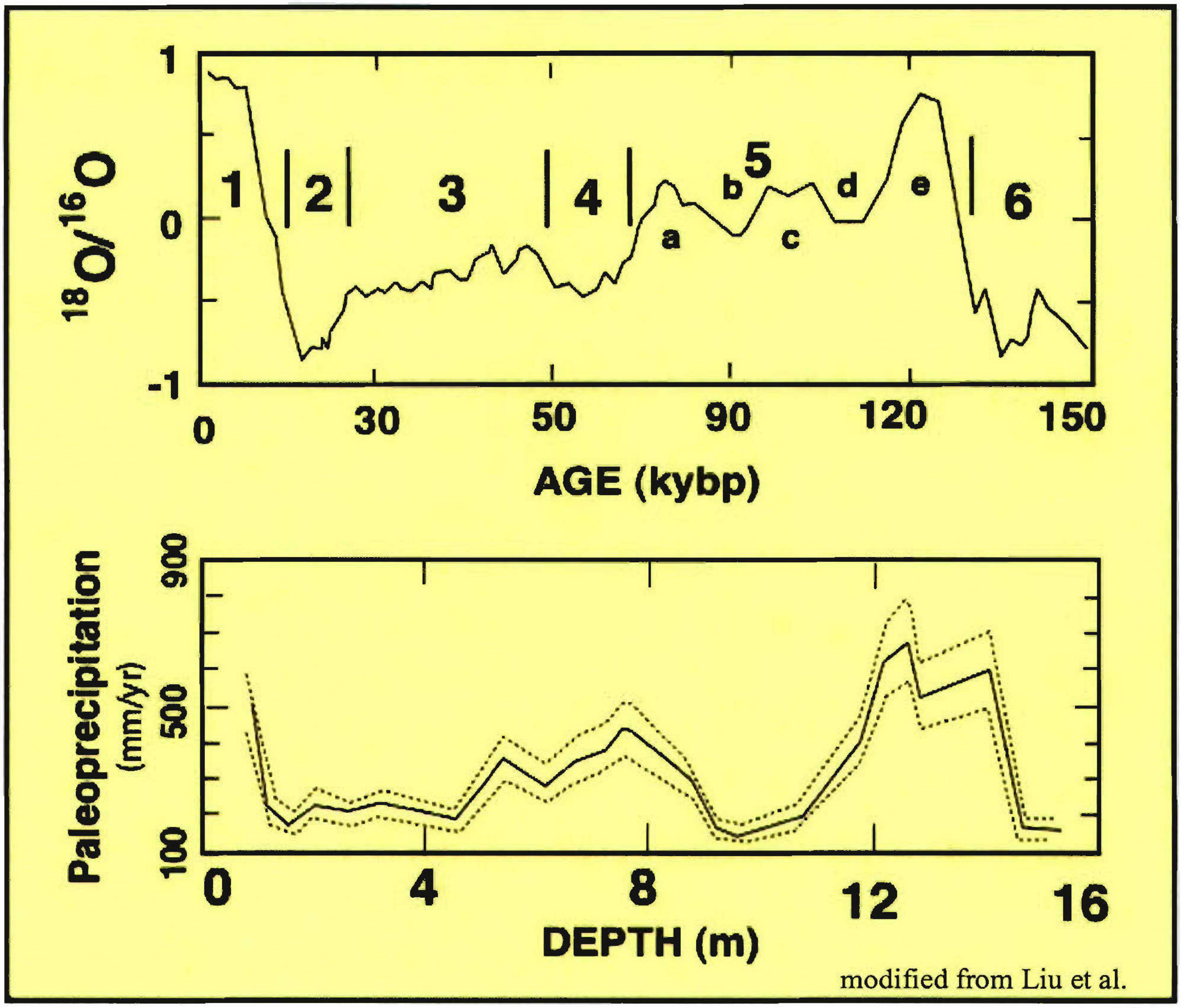

Figure 11: Plots of the variation in oxygen isotope ratios versus time and paleoprecipitation versus depth from core from the Loess Plateau of China. The oxygen isotope ratio is an excellent proxy for transitions from global ice ages to warm intervals and the associated changes in sea level (see Figure 5). The paleoprecipitation curves were derived from variations in grain size and magnetic susceptibility in core. The comparison of the two curves reveals that there were significant changes in precipitation in the region as the global climate changed and these variations had an important impact on the discharge of rivers and thus sediment supply to the ECS margin. The important trends are that when sea level is high the precipitation is greatest and the rivers were transporting the largest load of sediment to the basin when accommodation was highest. During the intervals when sea level was falling and low, paleoprecipitation was lowest and the rivers did not have the discharge to transport the available sediment. Consequently there was much aggradation and avulsion and limited incision. So the climate had an impact on margin architecture that was as great as that of sea level, which is not consistent with many sequence stratigraphic models.